AD-A167 053 VOICE/DATA INTEGRATION IN THE PBX (PRIVATE BRANCH EXCHANGE)(U) AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH M A BULL 1985 AFIT-CI-NR-86-58T 1/2

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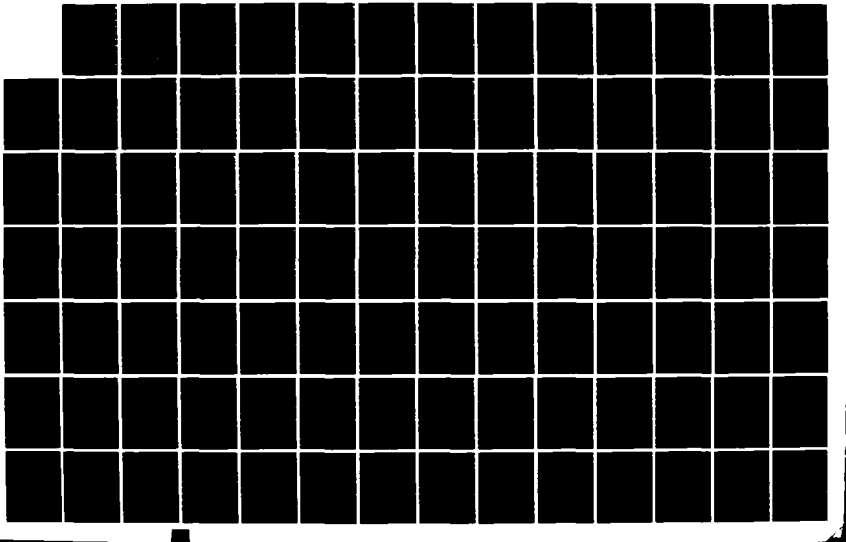

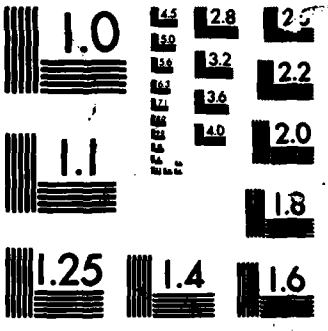

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SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER AFIT/CI/NR-86-58T	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE *(and Subtitle)* Voice/Data Integration in the PBX		5. TYPE OF REPORT & PERIOD COVERED THESIS/DISSERTATION
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Michelle A. Bull		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS AFIT STUDENT AT: University of Colorado		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS AFIT/NR WPAFB OH 45433-6583		12. REPORT DATE 1985
		13. NUMBER OF PAGES 101
14. MONITORING AGENCY NAME & ADDRESS*(if different from Controlling Office)*		15. SECURITY CLASS. *(of this report)* UNCLASS
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

AD-A167 053

16. DISTRIBUTION STATEMENT *(of this Report)*

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

17. DISTRIBUTION STATEMENT *(of the abstract entered in Block 20, if different from Report)*

18. SUPPLEMENTARY NOTES

APPROVED FOR PUBLIC RELEASE: IAW AFR 190-1

LYNN E. WOLAVER 12 May 86
Dean for Research and
Professional Development
AFIT/NR, WPAFB OH 45433-6583

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

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20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

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Voice/Data Integration in the PBX
Project directed by Professor S. W. Maley

Throughout most of its 100 year history, the Private Branch Exchange (PBX) has been used to transmit analog voice signals. In the last decade, however, the proliferation of computer technology and the merging of computers and communications have converged to make digital data communications of increasing importance. The emergence of this relatively new field has been acknowledged by equipment vendors through the development of new products that handle data in its original form and deal with some of its idiosyncracies. Among these new products is the integrated voice/data PBX, the latest result of the ongoing evolution in switching technology.

Integration of voice and data takes place in three areas of the PBX: the user terminals, the inside wiring and the switch itself. Different vendors use various methods and technologies for achieving integration. Not all vendors, however, include some of the necessary features, such as a nonblocking architecture, for the integration of very different types of signals.

Vendors claim that integration brings with it

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cheaper wiring, lower cost, and simpler total communications than other alternatives. These claims are questionable. Integration does provide simultaneous transmission of voice and data, fairly high data speeds, good reliability, and an ideal medium for personal computer communications, and it gives data access to many resources and services. However, given the data communications need of many businesses, an integrated switch may offer far more capability than is necessary for the foreseeable future, and at higher cost than other data alternatives. These alternatives may not have the speed limitations of an integrated PBX. In addition, integration technology is changing rapidly; neither the technology, the products, nor the vendors are particularly stable.

Given these disadvantages, users may look to other types of data transmission products, such as modems, data over voice products, data switches and local area networks. These products, too, have their advantages and disadvantages; but they may well be the wisest course to choose until the integrated PBX matures and becomes a more universal product, able to switch all types of data and voice signals efficiently and economically.

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VOICE/DATA INTEGRATION

IN THE PBX

by

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A project submitted to the

Faculty of the Telecommunications Department of the

University of Colorado in partial fulfillment

of the requirements for the degree of

Master of Science

Program in Telecommunications

1985

This project for the Master of Science degree by

Michelle A. Bull

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has been approved for the

Program in

Telecommuniations

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Date 17 Dec 1985

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CHAPTER 1

INTRODUCTION

Traditionally, the Private Branch Exchange (PBX) has had the role of switching voice communications. This single function role has changed dramatically in the last few years. Rapid technological advancements in conjunction with a changing office environment are forcing PBXs to incorporate data communications along with various office automation capabilities. To do so efficiently, PBXs must be able handle voice traffic and data traffic equally well. This requirement to provide transparent communications of both types to the user is a major driving force behind the present furor about the integration of voice and data through one switching device, the integrated PBX. The purpose of this study is to explore the integration of voice and data in PBXs from several viewpoints including historical, technical, and philosophical.

In Chapter 2, a history of the PBX will be presented. It will trace the evolution of the PBX from its early days up to current integrated applications. Major technological advances in representative major PBXs will be outlined.

Chapter 3 will look at the techniques used in PBXs to integrate voice and data. A general overview of a generic integrated PBX system will be shown followed by a detailed look at three current integrated switches. At the end of the chapter will be a tabular presentation of the capabilities offered by integrated PBX vendors.

The next chapter will discuss the advantages and disadvantages of using a PBX to integrate voice and data traffic. Voice/data integration involves more expense than simpler techniques and PBX vendors claim a host of advantages to justify the additional expense. This chapter will take a close look at those claims in addition to the disadvantages associated with the integration of dissimilar traffic types through one switching device.

When the disadvantages of using an integrated PBX outweigh the advantages, alternative methods of transmitting voice and data can be used. Chapter 5 highlights four of these methods.

Chapter 6 will discuss the market environment in which the integrated PBX resides. It will present the current market structure in conjunction with some of the dynamics affecting that structure. The latter part of the chapter will look to the future of the PBX market through discernible trends.

The last chapter will present the conclusions of this study. After the last chapter will be two appendices providing supporting material to this study.

CHAPTER 2

THE EVOLUTION OF THE INTEGRATED PBX

Before beginning a detailed explanation of the current state of voice/data integration in the PBX, it will be useful to understand the evolution of the machine that makes this integration possible. This chapter will trace the evolution of the PBX from its early days up through contemporary switching techniques.

In the last decade, the concept of PBX "generations" has become popular as a means of describing the advances in switching technology. Unfortunately, there is little agreement among the various authors in the telecommunications field as to when the generations begin and end, and what characteristics they embody. It depends upon when one considers that PBXs developed--with manual or automatic switches--and how much change and innovation is necessary for a new generation to be born. Therefore, the distinction between generations seems to be an artificial one, especially in view of the very rapid pace at which technology is progressing today. A more valid approach to describing the evolution of PBXs appears to be simply to outline the major technological advances that have occurred over the last century, and to illustrate these developments with some

of the major switches. This approach will be followed throughout the chapter.

The first PBX systems to enter the business world were essentially smaller versions of central office switches. Throughout their history, PBXs have been modeled on these larger systems. Advances in switching technology have been quickly incorporated into both PBXs and central office switches.

The earliest PBXs, which appeared in the late 1800s, were manual cord switchboards.[1] In these systems, a telephone attendant manually connected two stations or a trunk and a station using two cords with plugs that were inserted into the appropriate jacks. The system was completely analog, and any multiplexing was space division (that is, the cords formed a dedicated path for each conversation). Naturally, given the technology of the era, it was a voice-only system, and seems fairly primitive by today's standards. Nonetheless, it was composed of the same four basic elements that make up PBXs today: common control, switching matrix, trunks, and user terminals or telephones.[2] In this case, the common control was a human operator making physical connections.

Switchboard operators began to be phased out when the first dial PBXs were introduced in the late 1920s. These systems used electromechanical step-by-

step switching equipment to replace the human element on intercom calling and outgoing calls. A human operator was still responsible for supervising incoming calls and transfers. The systems still used analog loops and analog switching. Data communications, when it became necessary, was done via modems. This type of system was typified by Bell's 701 family of equipment.[3] During the 1950s and 1960s, the step-by-step systems were modernized: later versions replaced switchboards with attendant consoles and provided direct inward dialing and other features.[4]

The 1950s also saw the development of another kind of electromechanical dial switch--the crossbar PBX. The major advantage of this type of switch was that common control replaced progressive (step-by-step) control, thus allowing improved line- and trunk-hunting algorithms and lowered cost for tone dialing service. Incoming calls were still answered by an attendant, but consoles rather than cord switchboards were used. In addition, these systems were smaller and quieter than previous systems. The major crossbar PBXs manufactured by Bell were the 756, 757 and 770.[5]

During the 1960s and 1970s, another type of PBX was developed and came into use. This was the wired-logic electronic PBX, a system that used solid-state

devices for the logic elements in the common control and a variety of devices for the switching matrix. For example, the Bell 800 and 801 PBX matrices used reed relays, the 805 PBX used full-size crossbar switches, and the 812 PBX used miniature crossbar switches. As with earlier PBXs, the design of the switching components was taken from central office switches; however, the remainder of the hardware and the wired-logic solid-state common control were unique to this PBX.[6]

All of these types of systems, from manual switchboard to solid-state PBX, were still in use to some degree in the mid-1970s. It was then that a major development occurred in switching technology: the computerized PBX. The computerized switch used the intelligence present in stored program control (SPC) to restore many of the functions that had been available with a human operator, such as call forwarding, ring back and control of abuse/misuse. It also offered enhanced functions, including least cost routing and programmable moves and changes. Although these PBXs were often termed "digital," they were actually digitally-controlled analog switches; that is, switching was digital, but the loops remained analog. Thus, modems were still necessary for transmission of data.

These SPC switches were originally designed to handle voice traffic only. Any data capability that

these switches now possess is a result of additions or changes to the device.[7] This creates problems for both voice and data users. Because voice conversations are generally short, a voice-only system does not need a nonblocking architecture; it is unnecessary to include enough talking paths to accomodate each pair of ports. However, when even a small amount of data, with its long holding times, is added to the system, an unacceptable level of blocking may occur. When data users experience blocking, they may respond by grabbing a line and holding it all day, whether or not they have anything to transmit. It is easy to see how the problem could grow. Another difficulty with a PBX that is designed for voice only is that data rates will be quite low, perhaps only 9.6 kilobits/second (Kbps). Examples of this type of "digital" PBX include AT&T's Dimension PBX and the early Rolm and Northern Telecommunications Inc. (NTI) offerings, which appeared around 1975.

Data capabilities were greatly increased when the stored program control switch went totally digital. Digitizing of the analog voice signal was now done at the handset rather than at the switch as had previously been the case. This was done by incorporating a codec (COder/DECoder) into the digital telephone itself (see Appendix A for voice digitization techniques). With an

all digital system, data handling was much easier, within the office, at least. Before the voice signal could go outside the digital office environment, it had to be returned to analog form in order to be transmitted over the predominantly analog public switched telephone system. However, while still within the office, digital lines made data transmission much simpler. Instead of using modems to convert the digital data to analog and then back to digital at the switch, data could be sent over the digital lines by means of a data terminal interface (DTI). This data module uses a line driver with an RS-232C interface and a telephone jack. It is usually connected to the switch by three twisted pairs, one for voice and two for data (transmit and receive). The three pairs are connected to the switch by a data line interface (DLI), which is simply a line card housed in the PBX common equipment.[8] These multiple wire pairs make possible the simultaneous transmission of voice and data. However, the two signals are not physically integrated, as they are being sent over separate facilities.

The first integrated voice/data PBX was Intecom's IBX, introduced in 1980.[9] It was matched fairly quickly by offerings from other manufacturers, including AT&T's System 75, Rolm's CBX II, and the NEC NEAX 2400. These products have similar general character-

istics beyond integrating voice and data. They incorporate nonblocking operation, meaning that they can handle the increased loads and longer holding times associated with data communications, particularly with time-sharing applications. In addition, they feature distributed architecture, meaning that control of the system is distributed over switching modules, instead of centralized in one processor.[10] The switching modules are generally connected via fiber optic or coaxial cable.

Distributed architecture has been the source of disagreement among various vendors. This type of topology can simplify cable management, especially in a complex campus situation. It is also more reliable than a centralized system, as there is no single point of failure. And it provides better load-sharing than the traditional centralized or "hierarchical" architecture. However, hierarchical PBXs probably perform better under heavy-load conditions since they do not have the internodal control and synchronization problems that fully distributed systems encounter. Despite the latter argument, distributed processing will probably dominate in the future due to the increasing power and decreasing cost of computer intelligence.[11]

With the introduction of integrated transmission and switching, new features and capabilities were

made available. The most important of these were greater data speeds and line capacities. Speeds of 19.2 Kbps for asynchronous and 56 Kbps for synchronous transmission were common.[12] And once the data reached the border between the digital environment of the office and the analog environment of the public telephone network, it was decoded via modem pooling. These truly integrated switches also included interfaces designed for data devices such as terminals and facsimile machines. An additional feature was extended transmission range, due to remote multiplexors (RMU). These RMUs were connected by fiber optic or coaxial cable.[13]

Advanced data capabilities did not mean that voice features were ignored. Voice capabilities continued to be expanded as the sophistication of the stored program control increased.

Since 1983, so-called "fourth generation" PBXs have been the subject of much discussion in trade journals and among industry representatives. Like the integrated voice/data IBX and others of its class, these devices are designed specifically to switch data and voice equally well. They take advantage of advances in computer intelligence to offer even more features for both data and voice transmission. These most recent PBXs are still something of an unknown quantity, as will be explained later. However, the following are

some of the features and qualities that distinguish them from previous machines:

* Data is mostly packet switched, rather than circuit switched. This eliminates blocking due to incapacity of the switch to handle the characteristics of data calls. Every terminal on the system should have access to the packet switched network.[14]
* Protocol conversion at the switch allows connection of data calls to public and private X.25 packet networks and other data networks.[15]
* The PBX is effectively integrated with a local area network (LAN). This may take the form of a LAN that is intrinsically part of the PBX architecture, or many LANs that are joined by a PBX as the hub or main switch. The LAN offers very high speed data transmission (in the megabit range) right to the workstation over a variety of media.
* The system is modular in both physical construction and in transmission capabilities. The first part means that hardware and software can be added to and subtracted from easily and inexpensively, and that the size

and features of the system can be easily expanded. The second part means that bandwidth can be allocated dynamically depending on the requirements of the communication.[16]

* Voice and text messaging are an integral part of the system.

These features and functions are in addition to those already attributed to earlier PBXs, including feature-rich digital handsets, distributed processing, nonblocking architecture and integrated voice and data over common twisted pair wiring.

These systems sound like a telecommunications manager's dream. And, for the most part, they have been just that: a dream, not a reality. Products that were announced as early as 1983 have yet to be implemented in any major installation. Ztel, maker of the PNX, a prime example of the fourth generation PBX, only recently emerged from Chapter 11 bankruptcy, and has yet to sell a single major system. CXC, the other start-up manufacturer of these very sophisticated switches, is also struggling to convince buyers of both the value of its Rose PBX and the long-term strength of the company.

Notwithstanding these companies' problems, and the doubts they cast on the claims of all vendors,

integration of voice and data is an established function on most major PBXs built in this decade. It seems to be a very much sought after tool, and one that is constantly pushed by vendors. The next chapter will examine the integration process in greater detail, and will take a closer look at techniques used by some of the major switches on the market today.

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CHAPTER 3

INTEGRATION TECHNIQUES

For many years, the dominant form of communications in the office has been voice. No doubt, in the future this will continue to be the case. However, there is an increasing need to handle data simultaneously with voice traffic and do so efficiently. By 1988, the investment firm of Hambrect & Quist Inc. predicts that the data line requirement for PBXs will be about thirty percent of all lines sold.[1] The office manager is looking to technology to handle this change in office operations through better information management tools. In the realm of telecommunications, such tools must be able to integrate the continuing voice requirement with the increasing requirement for low- and medium-speed data communications. This integration must occur at two distinct levels: the physical level and the logical level. The physical level provides gateways between various devices and networks from different vendors. The logical level provides the exchange of information between different user applications. The integrated PBX can provide both levels.[2]

This chapter will first examine integrated PBXs

in a general light as a system with three basic parts: the user's voice and data terminals, the inside cable plant, and the switch itself from line side to trunk side. Second, several representative integrated PBX offerings will be looked at in some detail. Finally, a summary highlighting the capabilities of integrated PBXs currently available will be presented.

TERMINALS

The integration of voice and data begins on the desktop of the user. True integration of voice and data requires a digital environment and, therefore, a digital voice signal. Most vendors use some form of PCM or DM to digitize the voice signal. Digitization can occur either at the PBX line card or in the telephone handset via a codec. Digitization at the handset results in the use of digital loops within the office environment and, subsequently, easy support of digital devices. This digitization at the source makes integration of voice and data practical.

One aspect of integration that makes it attractive is the consolidation of the various telephone and data devices now in use into a single instrument, the integrated voice/data terminal (IVDT). The IVDT can be defined as an alphanumeric display and keyboard combined with a telephone station set.[3] Although this

definition is fine in general terms, the various features offered by each IVDT model on the market today makes placing IVDTs in a single catagory a difficult task.

The IVDT is most commonly used as a telephone.[4] It contains a telephone handset, usually located on the display console or on the keyboard. Basic telephone features commonly found in current IVDTs include:

* automatic dialing
* last number redial
* call hold and call forwarding
* multiple line connection for simultaneous transmission of voice and data
* hands-free dialing

Differing levels of sophistication that provide more advanced features such as an electronic calendar with a reminder function, a "call me" list function, and electronic mail are built into each vendor's products in varying degrees.

In addition to these voice features, a wide array of data functions are also available. All IVDTs perform basic terminal functions, access internal and external data bases, and support asynchronous (ASCII) transmission. Some of the terminals have advanced emulation capabilities (e.g., IBM 3270 and DEC VT100)

and support other advanced data functions such as word processing. Some even have internal memory which allows for a personal computing capability. However, most of the current IVDTs are either dumb or smart terminals with telephony capability.[5]

Integrated terminals are technically attractive, but no one type of terminal can address all user needs. While an executive may find a small terminal that integrates voice and data functions very useful, an engineer involved with CAD/CAM will need a very different terminal. Although integration will move the specialized data terminal out of many offices and limit the use of the simple telephone, there will continue to be a use for such instruments and integrated PBXs will support that use.

INSIDE CABLE PLANT

The inside cable plant (i.e., in-house wiring) used in an integrated PBX system is comprised of pairs of twisted copper wire. Over these pairs, two basic forms of voice/data integration are found: physical integration and access integration. Physical integration involves voice and data equipment sharing the same housing, power supply, etc., but not sharing the same local loop to transmit over. One wire pair is used for the transmission of voice and a separate pair

for transmitting data. Each wire pair terminates on the line side of the PBX at a different line interface. The PBX itself is only physically integrated and, therefore, the two signals are never combined. In access integration, the voice and data equipment not only share the same housing and power, but also the same wire pair to the PBX and the same line interface.[6] In order to share the same wire pair, the voice and data signals are multiplexed together using either time-division or time-compression techniques. Time division is, by far, the most common of the two techniques.[7]

Twisted pair as a transmission medium can offer relatively high transmission rates. However, when used with an integrated PBX, it has practical limits imposed by the transmission speed of the equipment on either end and the switching limits of the switch matrix. Typically, integrated PBXs offer asynchronous speeds of 19.2 Kbps per channel and synchronous speeds of 56 Kbps per channel. A few offer 64 Kbps per channel. Often vendors will tout their products as providing much higher transmission speeds. This, however, is usually an aggregate measure. For instance, vendors may offer data speeds up to 2.048 Mbps which are derived by transmitting 64 Kbps over 32 simultaneous channels.[8]

THE SWITCH

Before reviewing several of the PBXs currently offering integration of voice and data, a number of important PBX aspects must be discussed.

GENERAL INTEGRATED PBX ARCHITECTURE

The architecture of integrated PBXs can be characterized very generally as distributed, non-blocking architectures based on a time division multiplexed (TDM) bus structure.[9] Distributed processing in a PBX is basically the use of nodes or modules to compose the total PBX system. These nodes are used to off-load some of the control function processing of the main switch. Each node can be either spread out over a geographical area or gathered together into one facility, depending on the requirements of the user. If necessary, a node can operate as an individual PBX which can greatly enhance system reliability.[10]

BLOCKING

With the integration of voice and data onto one switching matrix, blocking becomes a critical issue. Blocking refers to a situation where the switch becomes jammed with traffic. All available paths through the switch are being used and a user trying to place a call

is denied access and receives an equipment busy signal. Integration further aggravates the problem of blocking that a switch experiences. This is because data calls typically last much longer than voice calls. In a circuit-switched environment where a path through the PBX is dedicated to one particular call, the switch can become tied up with data calls and prevent timely voice call processing. Several vendors are trying to eliminate this situation and provide a totally nonblocking PBX.

A nonblocking PBX has sufficient real time processing capability to handle the maximum volume of voice and data calls simultaneously without experiencing a degradation of service. The current approach to complete nonblocking is implemented by providing separate switching environments within the PBX for voice and data: circuit switching over TDM buses for voice and packet switching over LANs for data. An integrated PBX that is totally nonblocking should not be confused with a PBX that is essentially or virtually nonblocking. Essential or virtual nonblocking means that the PBX is set up to provide a one in a million chance of a blocked call, based upon original traffic predictions. If traffic predictions are wrong, reengineering of the PBX's traffic patterns is necessary to obtain the desired level of service.[11]

PROTOCOL AND FORMAT CONVERSION

In an established switching environment, it is likely that there is an embedded equipment base of dissimilar devices using different formats and logical protocols. For instance, there may be occasion for an IBM 3270 to send information to a neighboring Wang terminal. Even with these two terminal types sharing the same network environment, they will not be able to communicate without the necessary conversion between their respective protocols and formats. An integrated PBX with the correct option can provided the necesary conversion service.

INTERFACES

The external interfaces provided by an integrated PBX are of considerable importance. They provide the ears to the world outside the PBX system. The two most prominent types offered by PBX vendors are T1 interfaces and X.25 interfaces.

The T1 carrier belongs to the digital transmission hierarchy of the North American public switched network. It operates at speeds up to 1.544 Mbps. There are five types of integrated T1 interfaces currently offered in the marketplace:[12]

1. Analog switched network services that provide standard trunk types (e.g., WATS)

over a T1 channel from the local central office to the PBX. Most voice/data PBXs use modem pooling to connect with this type (see Fig. 3-1).

2. Tie trunk services that entail a point to point link between two customer locations.

3. PBX to computer services that link the PBX with a mainframe. The two current competing stardards are the Computer-to-PBX Interface (CPI) offered by NTI and the Digital Multiplexed Interface (DMI) offered by AT&T.

4. Remote equipment group services that provide the capability for a remote piece of equipment to act as a full member of the main PBX with complete feature and function transparency.

5. Proprietary PBX-to-PBX transmission services that provide manufacturer-specific T1 interface between two customer locations without providing feature transparency between switchs.

The X.25 interface is the way that integrated PBXs access the world of X.25 public packet-switched networks. The interface is based on the X.25 standard

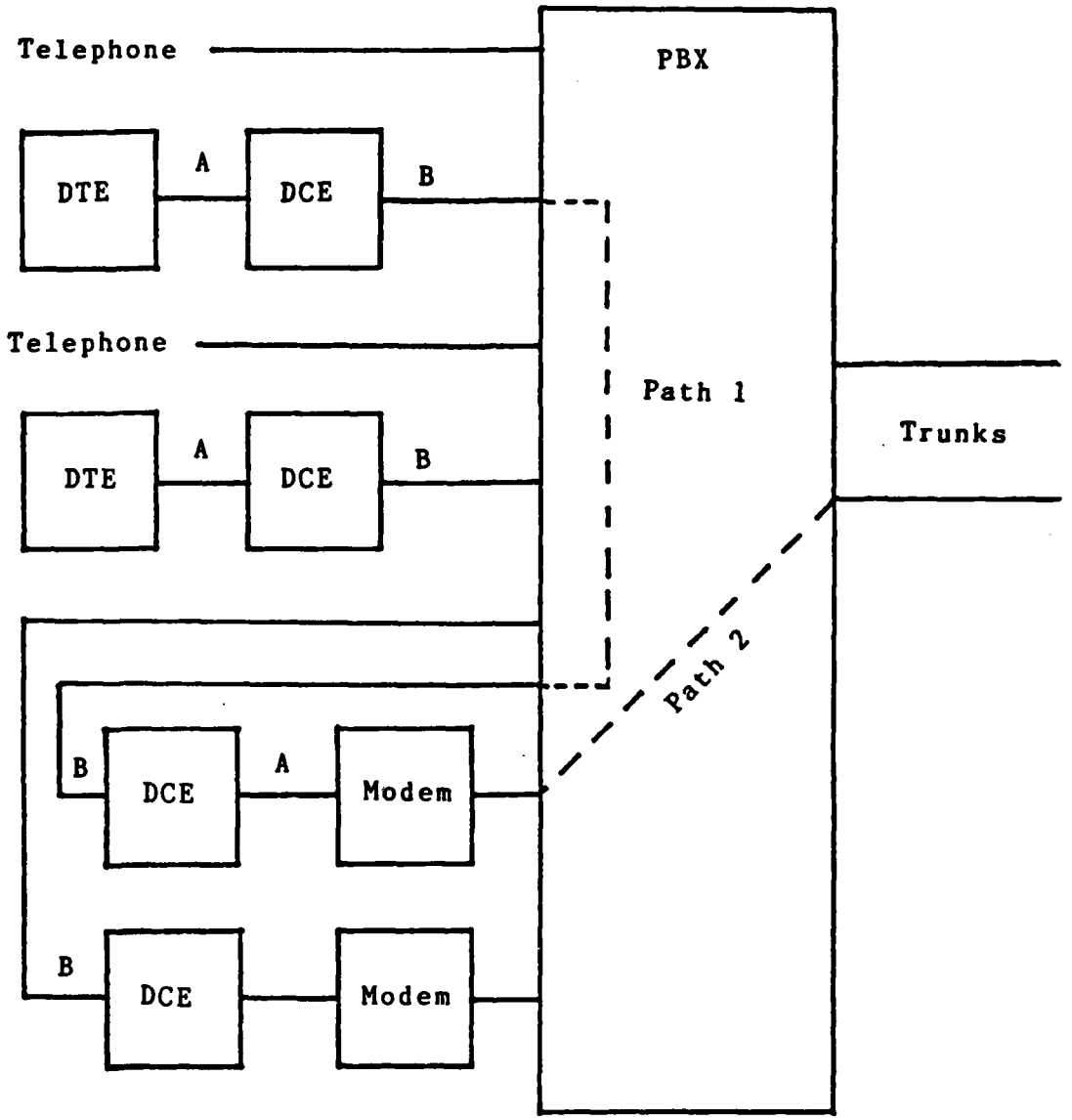

Figure 3-1 Modem Pooling

Source: Pardesi, M. A., "PBXs and data communications: what's available in the market," Telephony, vol. 207, no. 15, Oct. 1, 1984, p. 121.

developed by the Consultative Committee for International Telephone and Telegraph (CCITT). X.25 is strictly a user-network interface standard. The interface is accomplished by means of a resident packet assembler/disassembler that allows asynchronous terminals connected to the PBX to access public packet networks.[13]

OTHER ASPECTS

There are many other aspects to an integrated PBX such as number of lines, maximum data rates, and compatibility with RS-232C and RS-449 standards. These aspects and others will be presented in table format on a vendor basis at the end of this chapter.

THREE PBXS

This section will give general overviews of three PBXs that offer integration of voice and data. The three PBXs are the System 75 from AT&T, the CBX II from Rolm, and the Private Network Exchange (PNX) from ZTEL.

SYSTEM 75

The System 75, introduced in 1984 by AT&T, is a mid-size digital PBX that offers integration of voice and data. It can support 20-400 lines and 200 trunks. It is an essentially nonblocking switch using PCM

technology in a distributed switching and control architecture. Transmission of voice and data is provided at maximum of 19.2 Kbps asynchronous and 64 Kbps synchronous. A large number of features and services are provided including a user-oriented maintenance and administration capability.[14]

The switch architecture is composed of intelligent port circuits connected to a pair of TDM buses (see Fig. 3-2). Each of the parallel buses are eight bits wide and operate at 2.048 MHz which is equivalent to a single bus operating with 512 time slots. The bus structure provides redundancy in that if one bus fails, the switch can be reconfigured to operate at reduced capability on the remaining bus.

The bus bandwidth is divided between user information channels and a control channel that connects the control complex with the port circuits. The first five time slots on each bus are reserved for the control channel which is active on only one bus at a time. The first control time slot is used for addressing while the other four are used for control data.[15]

System 75 supports simultaneous voice and data using two wire pairs connected to one port. The voice signal is digitized at the user's terminal and multiplexed with data over the same pair. The communications mode between the PBX and the terminal is full

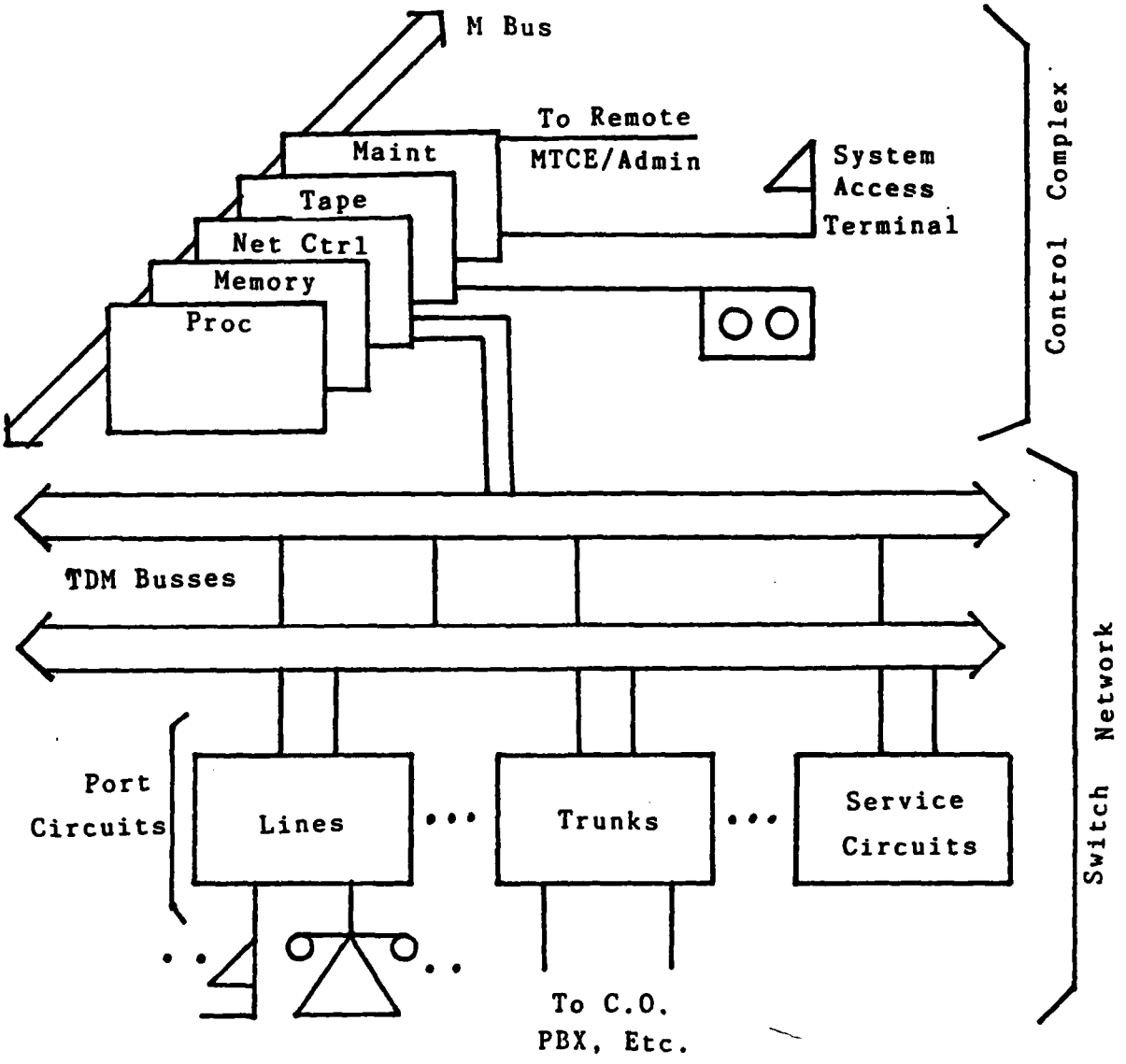

Figure 3-2 AT&T System 75 Architecture

Source: Feiner, Alexander, "Architecture, Design, and Development of the System 75 Office Communications System," IEEE Journal on Selected Areas in Communications, vol. SAC-3, no. 4, July 1985, p. 527.

duplex.[16]

Time-slot assignment circuitry at each port is used to establish basic voice and data connections. Assignment of transmit and receive time slots by the control complex is all that is needed to set up a connection through the switch. Both voice and data connections are circuit-switched. Voice signals are encoded using mu-225 PCM. Data communications use the Digital Communications Protocol (DCP), an AT&T protocol which provides two 64 Kbps information channels and a message-based signaling channel.[17]

Terminals usable with the System 75 range from simple single line telephones to the AT&T PT510 Personal Terminal which provides integrated voice and data capability.[18] Data modules can be used in a stand alone mode with data terminals or hosts to provide strictly data communications through a standard RS-232C serial interface. Data calls can be set up by either dialing directly from an ASCII terminal or from an integrated terminal. Protocol conversion and terminal emulation (e.g., IBM 3270) is supported by the System 75.[19]

The option to interface the System 75 to external packet switched networks is not available. There is, however, a packet interface called the Data Communications Interface Unit which provides a full

duplex X.25 interface between the main processor and proprietary UNIX-based applications processors (AP). These APs support system capabilities not directly related to switching such as call detail recording and facilities management. Access to the public analog switched network is available through modem pooling.[20]

CBX II

Rolm Corporation also offers an integrated PBX called the CBX II. A successor to the eight year old CBX line, it was released in November 1983. The CBX II is a fully-digital switch using 12 bit linear PCM and is virtually nonblocking for voice and data. It comes in two models: the 16-bit model 8000 and the 32-bit model 9000. The model 9000 can grow to accomodate up to 23,040 ports. Growth is accomplished through the connection of up to 15 CBX IIs as nodes. Linking the CBX II nodes can be done via either T1 circuits or fiber optic cable over the Internode Network (INN).[21]

The architecture of a single CBX II is shown in Figure 3-3. It is based on a series of TDM buses. User devices are connected over twisted pair to line cards on the interface shelf. The node contains three cabinets, each with six interface shelves of thirty-two cards apiece. Every shelf has its own small bus of 74

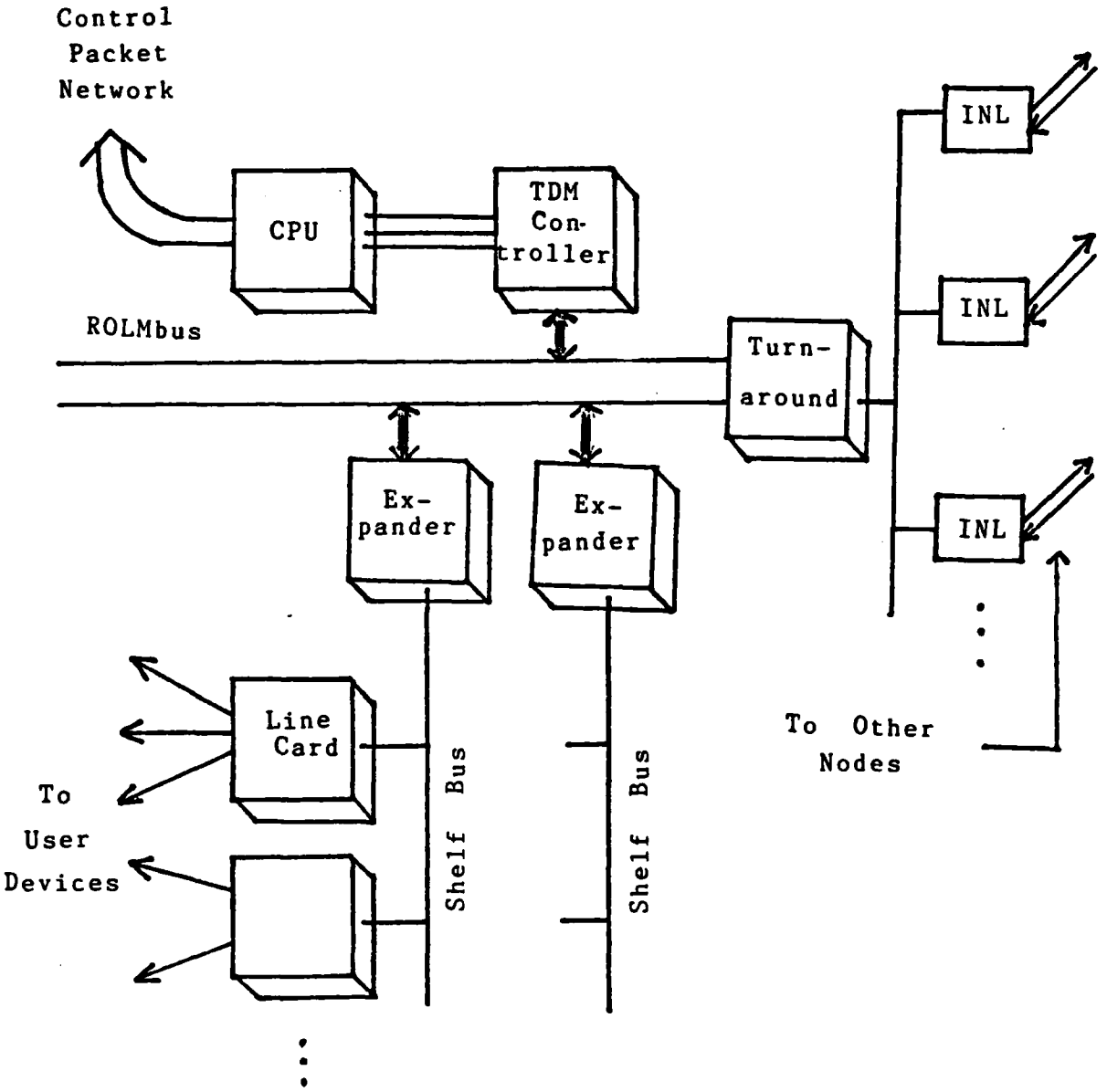

Figure 3-3 Rolm CBX II Architecture

Source: Kasson, James M. and Howard W. Johnson, "The CBX II Switching Architecture," IEEE Journal on Selected Areas in Communications, vol. SAC-3, no. 4, July 1985, p. 555.

Mbps that connects via an expander card to the main bus of the switch. This main bus is called the ROLMbus and comes in two variations: the ROLMbus 74 and the ROLMbus 295. The ROLMbus 74 operates at the same speed as the shelf backplanes, 74 Mbps. Transmission on the ROLMbus 74 is bidirectional. The ROLMbus 295 provides transmission speeds up to 295 Mbps, four times that of the ROLMbus 74. This is due to the nature of the transmission of the ROLMbus 295. It is unidirectional, being split into a source and destination bus.[22] Figure 3-4 illustrates the bus structure of the ROLMbus 295.

Integrated voice and data is supported by the CBX II through the use of proprietary integrated terminals. Two examples of these are the Rolmphone and the Cypress. In both terminals, voice and data are digitized at the handset and time-division multiplexed over the same pair of wires. Simultaneous voice and data is also available using an analog telephone and a data terminal connected through a proprietary data terminal interface (DTI). However, this situation requires three pairs of wire and is not truly integrated.

The CBX II provides asynchronous communications at 19.2 Kbps and synchronous communications at 56 Kbps. Interfacing with RS-232C devices is accomplished

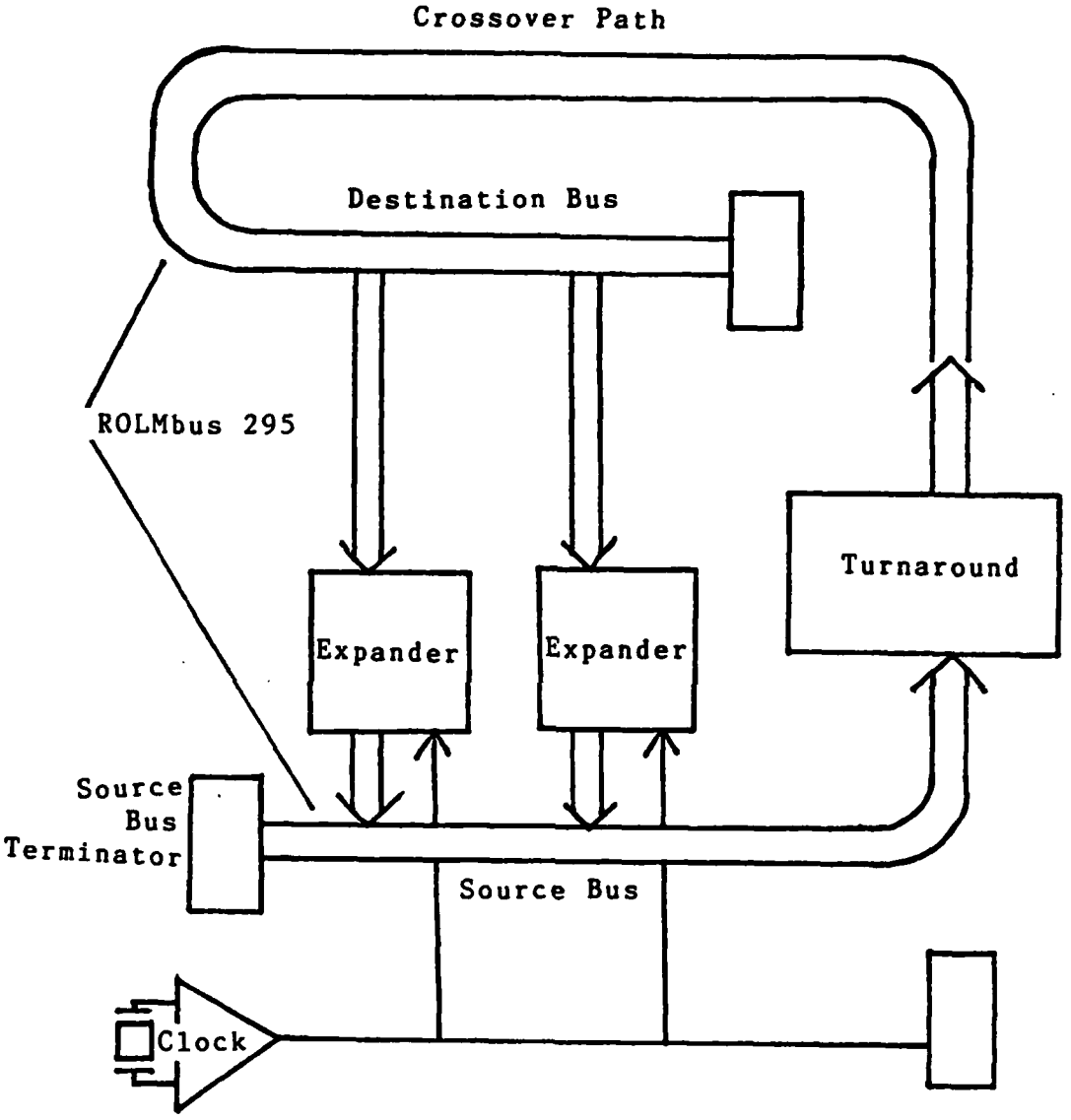

Figure 3-4 ROLMbus 295

Source: Kasson, James M. and Howard W. Johnson, "The CBX II Switching Architecture," IEEE Journal on Selected Areas in Communications, vol. SAC-3, no. 4, July 1985, p. 555.

through a DTI. RS-449 compatibility is not available. A sub-multiplexing technique is used to divide a voice channel of 96 kbps into a number of data channels.

The CBX II also provides various protocol conversions, format conversions and interfaces. For example, it can provide a gateway giving synchronous terminals access into an IBM host and then emulate an IBM terminal. Access into a public packet network is supplied by an X.25 interface called a Data Network Interface. Packet assembly/disassembly is performed by the switch. Modem pooling is used to reach analog switched network services.[23]

ZTEL PNX

One of the most recent developments in integrated PBXs is the Private Network Exchange (PNX) offered by Ztel. The PNX is an integrated voice/data switching system that is totally nonblocking and combines the voice features of a PBX with the data communication ablility of a LAN. It is basically a distributed microprocessor network made up of nodes called System Processing Units (SPU) interconnected by at least one data LAN and multiple voice LANs (see Fig. 3-5). The relationship between SPUs is peer-to-peer unlike many other PBXs which rely on one control node and other distributed nodes that are subservient to the

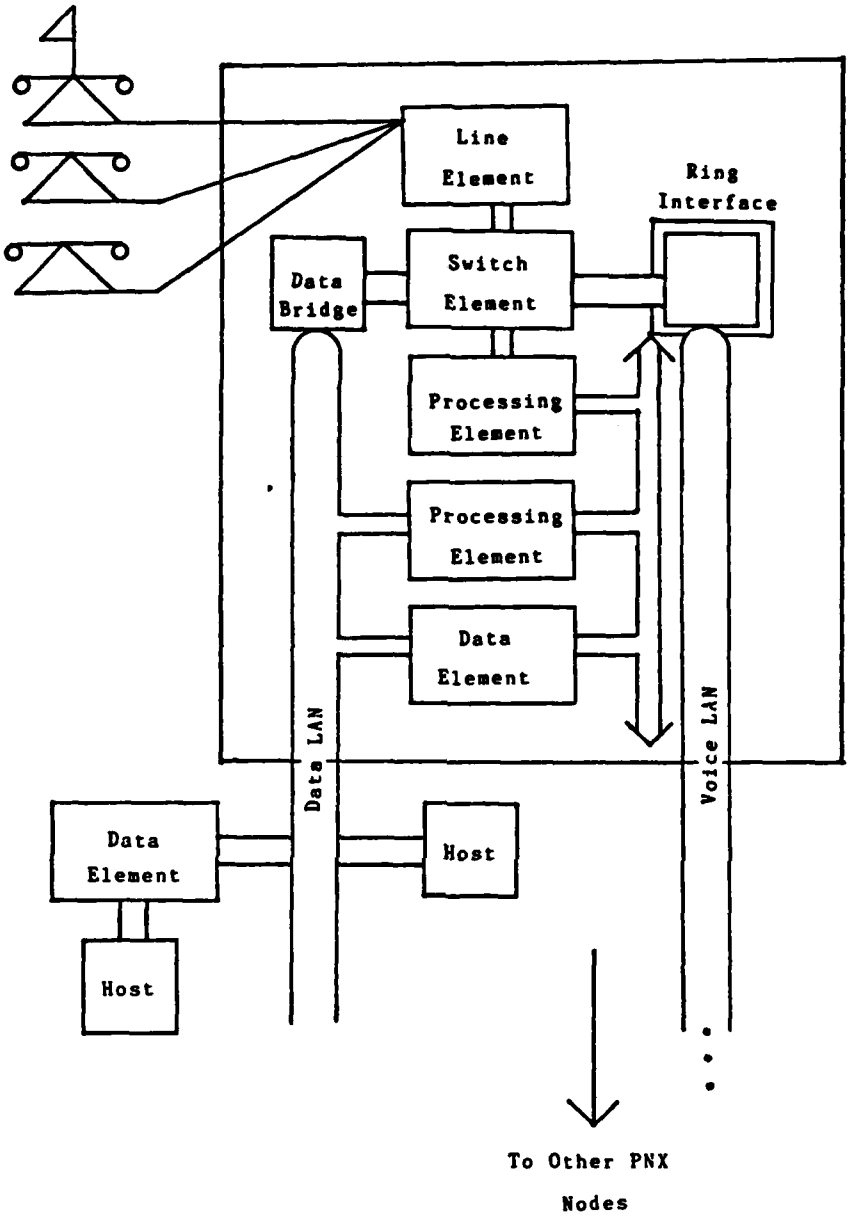

Figure 3-5 PNX System Processing Unit

Source: Zannini, Henry A. and Michael Patrick, "Fourth Generation PBX Explained," Telecommunications Products and Technology, vol. 3, no. 1, Jan. 1985, p. 42

control node. Each SPU contains Processing Elements which control voice and data line connections, protocol conversion and other system functions. Voice and data instruments are connected to an SPU over standard twisted wire pair. The PNX can support 256 nodes with up to 1,500 voice and data terminals per node.[24]

The data LAN is a token ring based on the IEEE 802.5 token ring standard. Operating in a packet mode at 4 Mbps, it passes both control information for the voice LANs and packetized data between SPUs. Packetization of data occurs in the Z/12 and Z/28 Telsets, proprietary integrated terminals produced by Ztel. Data access can be accomplished through RS-232C and RS-449 interfaces. Nonpacketized data is circuit-switched through one of the voice LANs at 19.2 Kbps asynchronous or 56 Kbps synchronous.[25]

The voice LAN is a proprietary token ring that is time-division multiplexed. It operates in synchronous mode and can support more than 220 voice calls per ring. The voice signal is digitized at the Telset or at the line element using PCM coding. It is then circuit-switched through the voice LAN at 64 Kbps. A voice call can be initiated from either the Telset or a standard analog 2500-type telephone.

Connection to the data LAN is not limited to strictly proprietary data devices. The PNX has the

capability to emulate other data environments such as IBM's System Network Architechture (SNA) environment.[26]

Access outside the PNX system is similar to other integrated PBXs. An X.25 gateway is used to access public packet networks. Modem pooling is used to reach the public analog switched network.[27]

A SUMMARY OF CURRENT INTEGRATED PBXS

The following table represents a summary of capabilities offered by the three PBXs just reviewed and other integrated PBXs.[28]

FEATURE	AT&T System 75	CXC Rose	GTE Omni	Intecom IBX	Mitel SX2000	NEC NEAX 2400	NTI SL-1	Rolm CBX II	Ztel PNX
Maximum Number of Lines	400	12K	2K	12K	5K	23K	400	23K	20K
Nonblocking			X	X	X	X		X	X
# of Ports for Simult. V/D	1	1	1	1	2	2	2	2	1
Number of Wire Pairs	2	2	1	2	2	2	3	3	2
Modulation	PCM	PCM	PCM	PCM	PCM	PCM	PCM	PCM	PCM
V/D Multiplex	X	X	X	X		X		X	X
Comm. Mode	FDX	FDX	FDX	FDX	FDX	FDX	FDX	FDX	FDX
Async. Data Speed (Kbps)	19.2	19.2	19.2	19.2	9.6	19.2	19.2	19.2	19.2
Sync. Data Speed (Kbps)	19.2	64	56	56	19.2	56	56	56	56
RS-232C Compatible	X	X	X	X	X	X	X	X	X
RS-449 Compatible				X					X
Modem Pooling		X	X	X	X	X	X	X	X
X.25 Interface		X	X	X		X	X	X	X
Protocol Convrsion	X			X	X		X	X	X
LAN		X		X				X	X

Table 3-1 Summary of Integrated PBXs

Source: Pardesi, M., "PBXs and Data Communications: What's Available in the Market," Telephony, vol. 207, no. 16, Oct. 8, 1984, p. 72.

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14. "AT&T Information Systems Dimension System 75," Datapro, TC07-070MQ, July 1984, p. 301.

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26. H. Zannini and M. Patrick, "Fourth Generation PBX Explained," Telecommunications Products + Technology, vol. 3, no. 1, Jan 1985, p. 41.

27. Pardesi (part 2), p. 85.

28. Ibid, p. 72.

CHAPTER 4

ADVANTAGES AND DISADVANTAGES OF INTEGRATING VOICE AND DATA IN THE PBX

As the preceding chapter indicates, integration of voice and data in the PBX is a complicated process requiring special techniques at the terminal and at the switch itself. These techniques necessarily involve some added expense over a simple voice-only switch. To justify this extra expense, integrated PBX vendors claim a host of advantages that their machines have over less sophisticated switches. These claims have varying degrees of validity. This chapter will examine both the real and claimed advantages as well as the disadvantages of voice/data integration in PBXs.

ADVANTAGES

The foremost advantage claimed by proponents of integrated PBXs is that the same wiring can be used for transmission of both voice and data. Instead of having to install expensive coaxial cable to connect data devices, all communications can use cheaper twisted wire pairs. And since more than 95 percent of offices in North America already have twisted pair in place, installation costs are eliminated in most cases.[1] In addition to these savings are the time and money saved

in terminal moves and changes, which are made much easier by using twisted pair. Terminals can simply be plugged into and out of a wall, using an RJ-11 telephone jack.

However, this argument overlooks some of the facts. Not all integrated PBXs actually integrate voice and data on the same wires. This means that they require more than one wire pair for simultaneous transmission of voice and data. So, unless communications planners have been unusually foresighted, they will have to install one or more additional wire pairs. One author claims that virtually all new PBX systems require completely new wiring plants.[2] Admittedly, twisted pair requires a minimum of engineering and is easy to install; still, the above possibilities show that the claims concerning cheap PBX cabling may be unfounded in certain circumstances.

Another major advantage attributed to integrated PBXs is lower cost than separate voice and data facilities. But again, this claim is only partially valid. In 1985, integrated PBXs are selling for between $600 and $1,600 per port. This compares very favorably to the $1,500 to $2,500 per port for a local area network.[3] However, a LAN is probably the most expensive of all data network alternatives. Data PBXs, data over voice, and modems are all cheaper technol-

ogies than integration for transmitting data (see chapter 5 for details on these alternatives). A voice-only PBX, through which data can be switched via modems, may be purchased for approximately $100 per port less than a voice/data switch.[4] Thus, if data communications are low, and few modems are needed, voice and data switching may be accomodated more cheaply on a less sophisticated switch.

The final major benefit claimed by integrated PBX vendors is the elimination of dual or multiple networks. All of the functions associated with the maintenance of a network can be centralized under one administration. This includes decision making, purchasing, expansion, service orders, moves and changes, administrative reports, testing and maintenance. Integration avoids duplication of both effort and expense. More important, it can provide compatibility between terminals, circuits, trunks and switching equipment.

However, many companies may not be ready for such centralization. Data processing and voice communications have traditionally been distinctly separate departments, often located in different divisions of a company, one technical, the other administrative. If management is unintegrated, then the question of departmental control of an integrated switch may arise. "Turf battles" may ensue, in which case it may be a

better business decision to simply continue with a non-integrated PBX.

Eliminating multiple networks may also eliminate multiple terminals on a user's desk, thus reducing clutter on the desk and in the office. This is done by replacing separate data terminals and telephones with integrated voice/data terminals (IVDTs). By consolidating various communications instruments into one, the IVDT gives office workers more space on their desks and simpler total communications.

However, this claimed advantage also has its drawbacks. An IVDT does indeed save space, but it does so at the expense of flexibility. When one device performs the functions of several previously separate devices, users lose several options: relocating just one of them, replacing or upgrading one, or buying them one at a time. In addition, most users probably own one or more of the devices that the IVDTs will replace. This means that users may be stuck with a lot of redundant, unamortized and perhaps unsalable equipment.

A true advantage that comes with installing a voice/data PBX is that the integrated switch offers data users access to many different resources. Rather than using different terminals for accessing applications in various computers, the PBX switches between many computers on request, thus making the terminal a

multipurpose workstation.[5] This workstation has access to computer ports for local applications, and to modems and multiplexers for connecting to remote computers.

In addition to these resources, the integrated PBX provides data transmissions with the same services that voice has traditionally enjoyed for many years, and which have helped to optimize the economics of voice calls: least cost routing (LCR), station message detail recording (SMDR), and connection to long-haul transmission networks via T1 interfaces. It also gives data users services that telephone users do not need, but which are very important in the data communications environment. These data services include interfaces to public and private packet switched data networks, gateways into IBM'S System Network Architecture (SNA), protocol conversion, error detection/correction and concentration of data onto high-speed lines.[6]

A second true benefit of integrated PBXs is a rather obvious one: they allow the simultaneous transmission of voice and data. This advantage goes beyond merely the convenience of not having to hang up the telephone in order to make a data call. Simultaneous voice and data opens up the world of mixed media communications, with such applications as voice mail, voice-annotated text and text-annotated voice. There is also work being done on voice-to-text conversion, which

would be a great leap forward in office automation.

Another valuable feature of the integrated PBX is that it allows fairly high data speeds within the integrated office. Speeds of more than one Mbps are possible over twisted pair between the terminal and the switch[7], and even higher speeds are common between processors (for a distributed system) over other media, generally fiber optic cable. Of course, once the signals reach the interface between the integrated office and the public switched telephone network, these high speeds are impossible to maintain with acceptable error rates. However, as 60 percent of all information travels within a single building to reach its destination[8], the limits imposed by the public network are not as restrictive as they might first appear: most information will indeed travel its entire path at high speed.

The distributed architecture that permits such high speed communication between processors also brings the advantage of increased reliability of the system. Multiple processors mean that there is no single point of failure for the PBX. And, since distributed architecture generally goes hand in hand with modular hardware, it also means that the switch is easy to expand. One simply adds to existing cabinets, sometimes merely by adding another processor to a stack.

The final advantage attributable to integrated PBXs is one that will be of increasing importance in the future. This is the increasing demand for the type of data communications that the integrated PBX handles best: asynchronous transmissions at 9.6 Kbps or less. Already, 90 percent of all office data communications run at or below 9.6 Kbps.[9] This percentage will probably go even higher as the effects of the personal computer (PC) revolution hit the data communications world. PCs, even more than other types of computer terminals, are perfectly suited to the type of data communications mentioned above. They generally run at 9.6 Kbps or less, asynchronously, using ASCII code and an RS-232C port, which is supported by all voice/data PBXs.[10] Also, PC traffic is more similar to telephone traffic than other types of data communications: it is light, and each connection is relatively short. PC users do not generally hold a line for hours, as is possible with other types of data users. In fact, PC traffic resembles telephone traffic quite closely in that connections are sporadic and brief, and communications can take place between any two devices. In contrast, most other types of data communications take place between terminals and a prefixed number of hosts.

Sophisticated PBXs provide many other benefits, due not to the integrated nature of the switches, but

to the fact that they are digital. That is, non-integrated switches could easily provide these benefits as long as they were digital. Prime among these benefits is the fact that the digital PBX will be in step with technological changes as the public switched network goes digital. This is already beginning to happen, spurred by the increasing availability and decreasing cost of digital network services, and the increasing demand for end-to-end digital services.[11] This process will eventually necessitate a digital switch. It will also eventually lead to an Integrated Services Digital Network (ISDN), whose diverse services will benefit only digital communications users.

Digital technology brings with it a host of other benefits, which will only be touched upon here as they do not relate directly to integration. These benefits include ease of multiplexing, ease of signaling, integration of transmission and switching, signal regeneration, operability at low signal-to-noise ratios, performance monitorability, ease of encryption, and accomodation of other services.[12]

DISADVANTAGES

Probably the best reason not buy an integrated PBX is that users simply do not need all those sophisticated applications. 90 percent of office communica-

tions are voice transmissions.[13] Experts predict that even by 1990, data communications will still compose only 30 percent or less of the total office communications load.[14] In a communications environment with low data needs, an integrated PBX may be overkill, and costly overkill at that. At $600 to $1600 per port, buying an integrated switch is more expensive than buying a voice switch; and it is far more expensive than making do with an old switch which, if not the leading edge in technology, at least performs all the functions that are needed. Getting rid of an old switch means losing depreciation and losing a less expensive investment that can often be upgraded to offer the desired features. Low speed data can always be switched via modems--it does not need expensive data interfaces to reach its destination.

Even if a firm has a large data network, an integrated switch may still not be justified if it cannot adequately handle the type of data with which the firm typically deals. Even the most sophisticated PBX cannot switch data at the high speeds that enable the transmission of full motion video signals or host-to-host communications. PBXs are not yet able to switch very high speed and high volume transmissions. Technology is still a limiting factor.

Providing that an integrated switch gives users

the functionality that they need, purchasing such a PBX may not be a wise decision. Integration technology is still in its infancy, with great strides yet to be made. The very high speeds and high volumes that are unavailable now may be achievable by the end of the decade, and the current features and functions will probably be obtainable at much lower prices, due to the decreasing cost of processor power. In addition, certain features claimed by vendors do not exist yet--they are still being developed, and are referred to by some users as "brochureware," because they appear to be attainable only in brochures. Waiting until these features are actually available, integration technology is better established, and PBX manufacturers are more stable, are good reasons to delay the purchase of a voice/data PBX.

Another disadvantage of integrated switches is that they destroy the safety net that having two separate networks can provide. By "putting all the eggs in one basket," integrated PBX users are leaving themselves more open to catastrophic failure of their whole communications system. Maintaining two systems gives the user more options in case of failure of either one.

Supporting two systems may also give users better overall communications. Critics of integration maintain that separate voice and data switches will do

their respective jobs better than one switch will do either job.[15] No single integrated PBX can do everything, but two switches may be able to perform all the functions that a user needs. With separate systems, purchasers can choose devices with capabilities that meet their particular requirements and that are compatible with their installed base of communications equipment.

A final disadvantage of the integrated PBX is that it combines two types of signals, voice and data, that have very different, perhaps incompatible characteristics. Voice and data have three basic differences: 1) As mentioned previously, data communications does not typically occur between any two devices; that is, traditional data devices tend to reach applications at a prefixed number of hosts or other dial-up locations. Voice terminals, however, can and do make connections to a wide variety of other telephones without regard to their location. 2) Data traffic is bursty in nature: data lines are inactive for long periods of time during which nothing is being transmitted, then they transmit a burst of data. In contrast, voice traffic is usually continuous once a connection is made. 3) Information on a data call is assumed to be more time sensitive than that on a voice call. Therefore, the data call demands instant connection, leading

to the requirement for a nonblocking switch for data applications. The voice call, on the other hand, copes easily with busy modes by queuing calls or attempting call back.[16]

The second difference, the burstiness of data traffic, is what makes integration of voice and data so difficult. When a data user grabs a line and holds it for a long period of time, the capability of the switch to process voice calls is reduced. When many data calls are occupying lines and processor power, the capability of the switch is severely affected. A true nonblocking integrated PBX can handle simultaneous voice and data calls from all ports. Only a few switches, Ztel's PNX and CXC's Rose, are totally non-blocking. This is accomplished by switching the voice and data separatly within the PBX: voice traffic is circuit switched over a TDM bus, data traffic is packet switched over a LAN. Unfortunately, packet switching is not presently conducive to voice traffic because of the delay involved. Therefore the packet switched data and circuit switched voice must be separated over the local access lines. However, AT&T's Bell Laboratories was recently issued a patent for a packetized voice technique that, according to one author, "could eventually become the primary means for switching voice calls over telephone networks..."[17] Until this tech-

nique becomes practical, integrated PBXs must perform special functions, such as packetizion of data and separation of the two signals, in order to prevent data from overburdening a switch. PBXs that do not perform this function cannot claim to be truly integrated voice/data switches, as they do not handle voice and data with equivalent ease. These others are only virtually or essentially nonblocking, a limitation which means that a large number of data calls will overwhelm the switch.

NOTES-CHAPTER 4

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CHAPTER 5

ALTERNATIVES TO VOICE/DATA INTEGRATION

The previous chapter discussed some of the benefits and costs involved in integrating voice and data communications in an integrated PBX. Although the benefits are many, the drawbacks are numerous and serious enough to make communications managers look for other solutions to the problem of transmitting two different types of signals throughout an office or campus. The voice communications portion has generally been transmitted over wire pairs, via a key set, PBX or Centrex system. Various schemes, however, have been used to transmit the data portion of a communications system. This chapter will discuss these different methods of data transmission, including: modems, data over voice, data PBXs and local area networks.

MODEMS

The oldest, simplest and cheapest method of transmitting data through a PBX is via a modem. A modem is a device that converts digital data signals into audible tone or analog signals for transmission over ordinary telephone wires. Data cannot be passed over telephone wires in their original digital form

because of the bandwidth limitations of the loaded telephone channel. The direct current (zero Hz) portion of the digital signal is outside the 300 to 3400 Hz passband of this channel.[1] The telephone system amplifiers and filters will distort digital square-wave signals into unrecognizable garbage, even over short distances.

A modem handles this problem by MOdulating and DEModulating the signal so that it fits the above parameters, hence the word "modem". That is, at the transmitting end it converts binary electrical signals into voice-frequency analog signals; it does the opposite at the receiving end. Type of modulation generally varies with the speed of the modem. Low speed (300 bps) modems usually use frequency shift keying (FSK), whereby a one is transmitted at a certain frequency and a zero is transmitted at a frequency 200 Hz higher. The base frequency depends upon whether the modem is in the originate or the answer mode. Medium speed modems (1200 and 2400 bps) typically use phase shift keying (PSK), as it takes less bandwidth than FSK. Higher speed modems (4800 bps and above) use more sophisticated forms of PSK, such as quadrature amplitude modulation; however, this complex type of modulation greatly increases the price of the modem, so that it may cost even more than the terminal or PC that is the source of the

data.[2]

There are many ways to classify modems other than by speed. External modems are stand-alone devices that need a cable and an RS-232C serial port to connect to the computer or terminal, whereas internal modems are cards or expansion boards that fit into the input/output (I/O) slot of the computer and take data directly from the I/O bus. Internal modems are more compact, simpler and cheaper, but they can only be used on the kind of computer for which they were designed. In contrast, an external modem will work with almost any type of data producing device.

Modems may also be classified by their features, or level of intelligence. As costs for memory and processing power decrease, modems with many features are becoming more popular, with the Hayes Smartmodem as the de facto standard against which the competition is measured.[3] Features include automatic dialing, automatic response, repeat dialing, dialing directory, protocol detect and switch, self-test, help command, and several other commands that make usage simpler or more reliable.

A low speed, no frills modem can be purchased for about $80, a full featured one like the Hayes for about $290. This cost range is well below the cost per port of an integrated PBX and makes the technology seem

attractive. However, as soon as the operating speed of the device increases, the cost also rises. Dual low speed modems (1200/300 bps) are averaging approximately $550, and dual medium speed devices (2400/1200 bps) typically cost over $800.[4] It should be noted that these higher speeds usually bring increased error rates as well as increased prices.

One new way of using modems has recently been introduced by AT&T, using its enhanced Centrex service and 1A ESS and 5ESS central office switches. Using integrated voice/data modems, the user sends voice and/or data signals to the telephone company's central office. The data signals access a modem pool, then both signals are sent over the public telephone network. This feature allows Centrex customers to use slow, inexpensive short-haul modems on their facilities, while placing the cost of the faster (9.6 Kbps), more expensive, long-haul modems on the telephone company. A modem pool can be dedicated to one large Centrex customer, or it can be accessed by many customers.[5]

Modems of all varieties will probably always have a place in corporate and personal data communications. Low speed modems certainly cannot be beaten for cost, although their performance level may also be low. However, with computer intelligence becoming more pow-

erful and less expensive, integrating voice and data in a PBX may eventually be a better way to go, when one considers both features and cost. Integrated PBXs offer all the advantages of digital switching and transmission, advantages that the modulation process eliminates. Integrated PBXs provide much higher speeds than modems, access to more resources, and possibly simpler operation. They also get rid of one more box on the desk, and another set of wires on the floor.

DATA OVER VOICE

Data over voice (DOV) systems take advantage of the fact that voice signals use only a small portion of the bandwidth available on twisted wire pairs. Voice transmissions (both audio and signaling) are band-limited to 4 KHz or slightly less, leaving a large spectrum above this frequency that can be used to transmit data in analog form. The DOV process is also called "piggybacking," as the data signal is transmitted on top of the voice signal.

A DOV device acts as a filter, modem and multiplexer all in one. That is, the device frequency filters the analog voice signal to ensure complete separation of the voice and data streams. It then modulates the digital data stream, converting it to analog form, and then frequency division multiplexes the data sig-

nals at higher frequencies (36 to 178 KHz) onto a wire pair that also transmits voice signals at under 4KHz. The data channel in the upper frequncy range is further subdivided to permit full-duplex (transmit and receive) communications.[6] The data and voice signals are separated either by circuit cards at the PBX or by a data PBX. With a circuit card, voice signals remain at the PBX to be processed, while data signals are routed to a host computer. If a data PBX is used, voice signals are sent either to the voice PBX or to the central office (if Centrex service is being used). The data signals are switched by the data PBX.

DOV systems offer some of the same advantages as an integrated PBX. The system requires no new wiring, since the voice and data signals share the same single twisted wire pair. It eliminates the need for direct cabling (usually expensive coaxial cable) between the terminal and the switch, although cabling between the switch and computer room must still be dealt with.[7] The DOV unit, the terminal and the telephone can all be plugged into the nearest wall telephone (RJ-11) jack. This situation greatly simplifies adds, moves and changes, and can save up to $200 for every terminal move.[8] Data transmitted over a DOV unit can connect, via the voice or data switch, to outside resources such as LANs, T1 lines and value-added

(packet switched) networks. DOV costs range from $400 to $600 per connection, which is about 50 percent of the cost of the fully integrated approach.[9]

However, DOV systems have some serious limitations. The maximum distance allowable from the workstation to the telephone processor is about 16,000 feet, although this figure varies by thousands of feet from vendor to vendor.[10] And as the distance increases the transmission speeds diminish, because higher speeds suffer greater signal distortion. Speeds of 19.2 Kbps are available for distances ranging from 6,000 to 15,000 feet, but most vendors offer speeds of only 9.6 Kbps.[11] DOV systems have traditionally been confined to use in asynchronous transmissions, but recently there has been adaption for limited use in synchronous networks. Many vendors, however, still offer only asynchronous equipment.

In addition to these limitations is the disadvantage imposed by the public switched telephone network. Loading coils are placed on the local loops every three miles in order to maintain transmission quality. In so doing, the coils limit frequency to the 4 Khz needed for voice transmissions, thereby destroying the higher frequency data signals. So, DOV is only good for intraoffice communications, or for communications to and from offices located within three miles of

the local telephone company's central switching office.[12]

One final disadvantage concerns the cost of DOV systems. While they are generally less expensive than integrated digital voice/data systems, they are by no means the cheapest systems available. Limited distance modems, costing less than $100, can channel data over greater distances, and provide fault diagnosis as well. Also, one integrated switch vendor claims that DOV costs are misleading because they do not include the cost of a new or existing voice PBX. Once the cost per connection of the voice switch is added to that of the DOV device, the total cost is not much less than that of an integrated PBX.[13]

Considering all these advantages and disadvantages, and the fact that they work only in an analog world, DOV systems are seen as a bridge to a more sophisticated communications system. They provide a temporary and inexpensive way to integrate voice and data over existing telephone wires. But in view of a public network that is increasingly digital, an analog DOV system is one whose future is limited.

DATA SWITCHES

As mentioned above, data PBXs are one method for switching the data streams flowing on a DOV system.

Despite the attention and publicity that more sophisticated communications schemes have garnered, data PBXs are still regarded as the cheapest and simplest way of digitally switching computer terminals between one or more hosts.[14] They provide switching and contention to these terminals, allocating ports on a first-come-first-served basis. Users select the host or minicomputer that they wish to access, the data PBX queues for a port (usually less than a one second wait), and the connection is made.[15] Users may also access other resources connected to the data PBX; the terminals and computer ports may be either local or remote.

Data PBXs may be configured in two ways. If there is more than one pair of wires going to each workstation, then one pair may be used to connect terminals to the data switch. In this case, data remains in its original digital form. However, because digital signals experience attenuation as they travel over a distance, line drivers must be used to extend the distance of the signals for terminals that are located on different floors or in different buildings than the switch.

If, on the other hand, there is only one pair of wires going to each workstation, the voice and data must be frequency division multiplexed onto this pair using the DOV technique described earlier. Both data

and voice are transmitted in analog form, and no line drivers are used.

Using either type of transmission, data PBXs have been popular for specific applications since their introduction in 1972. Generally, they are best used for low speed switching of many asynchronous terminals between multiple hosts.[16] This is because their transmission speeds are limited to 9.6 Kbps, although a few vendors offer 19.2 Kbps. This limitation is similar to that of the data over voice technique. Data PBXs have another similar drawback in that they typically can handle only asynchronous traffic. Only two vendors, Micom and Codex, make devices that can switch synchronous traffic at 19.2 Kbps. These characteristics relegate both techniques to simple data entry and inquiry/response functions, rather than allowing them to switch large file transfers. Other disadvantages of the data PBX are that it has a single point of failure (although major data switches have redundant common logic) and that it does not provide port conversion.[17] The latter is needed to provide terminal emulation to attach non-IBM terminals to IBM hosts. In its absence at the switch, the emulation software must be provided in conjunction with a front-end processor.[18] This need for additional hardware and software will increase the cost of the configuration.

These disadvantages are offset by several benefits, the greatest of which is low cost. Data PBXs can be installed for $120 to $300 per port, a figure that compares well with the cost of an integrated PBX or a LAN.[19] This low cost is achieved by limiting bandwidth, as described above, and by sharing expensive components. In a data switch, the memory and processor power are shared by many users, whereas with a LAN, each terminal must have its own intelligence.[20] In addition, the data PBX can handle very large systems, up to several thousand lines.[21] Even large configurations are relatively simple to implement and have transparent operations, like plugging a terminal into the back of a computer.[22]

With advantages and disadvantages similar to those of a DOV system, the future of data PBXs is similarly bleak. The technology is cheap and accessible, but it is too limiting to be viable in the long run. Also, prices are decreasing faster for LANs and integrated PBXs than for the more mature data PBX market.[23] It may also face competition from data switching via enhanced Centrex. This being the case, data PBXs will continue to provide interim solutions to data switching needs, but will eventually be replaced by more sophisticated, flexible technologies.

LOCAL AREA NETWORKS

A local area network (LAN) is a transmission and switching system that provides high speed communications between devices located on a single site, typically within a one kilometer radius. A LAN is distinguished from other switching systems by its essential elements: restricted geographic area of coverage, low error rate, large bandwidth and consequent high speed of transmission (typically 500 Kbps to one Gbps). In addition, LANs are typified by a ring or bus topology rather a star configuration; this means there is no central switching node.[24]

There are probably as many types of LANs available as there are LAN manufacturers, but two types exist today that are most popular: baseband and broadband LANs. Both use coaxial cable as a medium. A baseband LAN carries only one transmission at a time, despite its bandwidth of one to ten Mbps. The transmission is in digital form, and therefore cannnot be sent beyond a few kilometers without using expensive digital repeaters. For this reason, it is best suited for use in small to medium sized departments. A broadband LAN, on the other hand, can carry many signals at once (up to 30 channels on one cable), each at a speed of one to five Mbps, giving a very large total band-

width. This larger capacity enables it to carry simultaneous voice, data and video traffic. The signals are carried in analog form. This means that the system requires modems to propagate the digital signal produced by the terminal or computer onto the analog RF carrier; it also means that the system may stretch for many kilometers using only inexpensive amplifiers. These characteristics makes it attractive for larger configurations.[25] Fiber optic LANs are also available, offering speeds up to one Gbps. However, access to and egress from these systems is still so problematic that they have not gained wide popularity. Fiber optic cable is used more to make external connections between LANs and PBXs or other LANs than it is to make internal local area connections.

The very high speeds available via LANs are in large part responsible for their increasing popularity in recent years. They realize the potential that exists in sophisticated computing devices for high speed communications and the applications that depend on them--videoconferencing, large file transfers, sophisticated graphics, CAD/CAM and host-to-host communications. Their powerful error checking and correction capabilities make them even more attractive to frequent data users, as does the fact that they allow intelligent devices to share resources, including

storage devices, printers, software and data files. The ring or bus topology means that there is no central point of failure.

Despite these strong points, LAN sales have not taken off as predicted. Only 45 percent of Fortune 1000 corporations had installed LANs in 1983.[26] This low figure is due to some serious drawbacks associated with LANs, the greatest of these being the confusion surrounding both the technology and the market. Unlike the telephone industry, there is no standard technology; this means that competing technologies and cabling schemes, and lack of compatibility make many users hesitant to spend large sums of money on a relatively unproven communications system. The presence of many new and unstable vendors and the reputation for high costs also contribute to this lack of enthusiasm. With cost per connection running anywhere from $1000 to $3000, it is not surprising that users may look to other solutions while waiting for the LAN market to stabilize.[27]

On a more technical level, the contention-based access scheme, on which most LANs run, leads to more problems. If a LAN is well planned and engineered, then a contention-based scheme will give rapid access to the system. However, if usage is higher than anticipated, contention will often lead to a delay that is considered intolerable. The delay factor also limits

potential growth of the system, since increased traffic will increase delay. Finally, contention-based delay means that voice communications are inconvenient, if not impossible, especially on a packet-switched LAN. Packet switching systems may soon be able to accomodate voice transmission, which will alleviate this problem.

It is evident, then, that LANs are not the solution to every communications problem. For simple port selection among similar computers and terminals with similar operating systems, a shared front end processor is generally more effective than a LAN. And for mutually incompatible computers and terminals, port selection switches or data PBXs are considered best.[28] In an environment of low speed, low intelligence terminals with a large degree of growth and mobility, an integrated PBX may be the best solution to implement. But LANs are increasingly gaining their share of the data communications market, especially as part of an integrated PBX-based solution. By themselves, LANs are appropriate where workstations are of high intelligence, where sophisticated and high speed applications are prevalent, and where the reliability of both the system and the data it transmits are of paramount importance.

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CHAPTER 6

THE PBX MARKETPLACE

To understand the specific market of integrated PBXs, one must look at the general PBX market. The PBX market has grown from a rather sedate market selling patchcord solutions in the early days of telephone to the sophisticated and confusing marketing environment of today that abounds with buzzwords and capabilities bordering on pure marketing hype. This chapter will explore the PBX market from two perspectives: the structure and dynamics of the current market, and the trends leading to the market of tomorrow.

THE MARKET

The market for PBXs is in reality a submarket of customer premise equipment (CPE). The CPE market, until recently, was largely the domain of only one vendor, AT&T. This monopoly by AT&T was possible because prior to 1968 it was illegal to connect user-provided equipment to the Bell switched network and other telephone company facilities. However, in 1968, the Federal Communications Commission (FCC) permitted the Carter Electronics Corporation to directly connect

its mobile radio system to the AT&T telephone network. They decided in their historic "Carterfone ruling" that

> "a customer desiring to use an interconnect device...should be able to do so, so long as the interconnection does not adversely affect the telephone company's operations or the telephone system's utility for others...The appropriate remedy is to...permit the carriers if they so desire to propose new tariffs which will protect the telephone system against harmful devices and they may specify technical standards if they wish."[1]

This FCC decision opened up the CPE, and consequently the PBX, market to any qualified newcomer. As a result, the near-monopoly AT&T held on the PBX market was reduced. As it turned out, the Carterfone decision was only the first blow to AT&T's market share.

The second blow came in 1982 in the form of the Modification of Final Judgement. Among other outcomes, the Modificaion of Final Judgement gave the newly divested Regional Bell Operating Companies (RBOC) the right to market CPE, including PBXs. This entrance of the RBOCs into the PBX market further reduced AT&T's share of the market as the RBOCs proved very willing to market PBXs not supplied by AT&T.[2]

Although AT&T's share of the PBX market has eroded, it still holds a significant percentage of installed PBX lines. As of July 1985, AT&T is still the leader with 30 percent of installed PBXs--down from around 40 percent in 1984. NTI and Rolm tied for a

close second at 23 percent. Other vendors trail in the distance with at most only a few percentage points apiece. Vendors holding less than one percent form a composite seven percent of the market.[3]

Further complicating the market share picture is the consideration of market segmentation based on line size catagories. There is a differentiation in PBX products based on line size. Some integrated PBXs provide only a few hundred lines while others provide many thousands. Vendors make different showings in different catagories (see Fig. 6-1). The expected top three vendors dominated in all line catagories. However, in the "under 100 lines" catagory, Mitel shows at a strong fourth with 15.4 percent. Other vendors hold, at best, only a few percentage points each in every catagory.[4]

While there is nothing very suprising in the market aspects discussed above, the PBX market is evolving in a new direction. Alliances are being formed between integrated PBX manufacturers and computer manufacturers. These alliances are indicative of the role the integrated PBX will play in future intra-office data communications. Most notable among these merging interests is the marriage of Rolm with IBM. Other examples of recently combined PBX/computer forces are Intecom with Wang and NTI with DEC.

NUMBER OF LINES	AT&T	NTI	Rolm
Under 100	30.8%	16.9%	27.7%
100-399	34.2	17.8	45.2
400-999	21.6	20.0	45.0
1,000-4,999	23.9	28.4	19.4
Over 5,000	38.9	38.9	5.6

Table 6-1 Market Segmentation of Installed Base in Relation to Line Size

Source: "PBXs: Market Still Ruled by AT&T, Rolm, and Northern," CommunicationsWeek, vol. 10, no. 27, July 22, 1985, p. C8.

These mergers are largely being formed to develop compatibility between PBX and computer products. Evidence of this is found in the present emphasis on computer/PBX interfaces such as the DMI and the CPI being recommended as standards to the Electronic Industries Association (EIA). DMI is being proposed by AT&T and HP while CPI is being proposed by NTI and DEC. These two interfaces, which are incompatible, specify the number of channels and the control signaling used to connect a PBX and a computer through one of the PBX's digital T1 trunk interfaces.[5]

The present market for integrated PBXs is by no means static. There are some discernible directions it will take in the future.

THE FUTURE

The road to the present integrated PBX market has been one dominated by AT&T followed by a few straggling competitors. However, recent years have seen AT&T's lead steadily eroded by other vendors. While the true future of the market is unknown, some trends exist that indicate the shape of things to come:

A Market Shakeout. One of the prominent trends apparent in the PBX market is an impending shakeout. Market competition is very fierce as there are too many companies

for too small a market. New market entries like CXC and Ztel will only further aggravate this situation.[6]

Market Share. The big three in the PBX market-- AT&T, Rolm, and NTI-- will continue to control the majority of the market with some in-roads being made by Mitel in the under-100 line segment. AT&T will continue to be effectively challenged by its two main competitors.[7]

Market Emphasis. Manufacturers will place more emphasis on the low-end market. The market for large line offerings is becoming relatively saturated and PBX manufacturers are searching for segments that have been previously unexploited.[8]

Market Growth. Market growth will become more moderate in the next several years. The early market growth rate of 13.2 percent annually was driven by four forces: the AT&T migration strategy of 1979 where older electromechanical PBX users were induced to migrate to the newer Dimension line; the mass exodus from Centrex use; the replacement of an aged and feature

poor installed base; and significant drops in system pricing between 1982 and 1984. New market forces in effect will dampen this earlier market growth to an annual rate of around three percent on the average. These new forces are the resurgence of Centrex sales, increased importance on the soft-dollar benefits of advanced PBX features, and new AT&T marketing strategies (e.g., the selling of their embedded leased PBX base and the marketing of refurbished PBX equipment).[9]

Mergers. As the desire for integrated communications and office automation grows, more mergers between PBX and computer manufacturers are likely to occur. Although it is unclear whether this merger strategy will be successful, industry analysts continue in the attempt to pinpoint likely candidates for marriage. The computer side of this matchmaking activity is heavy with potential mates--Motorola, DEC, Sperry, and HP to name a few. The PBX field is much less abundant, however. Mitel is probably the strongest contender with a few newcomers such as Ztel, CXC, and Telenova as other merger possibilities.[10]

Improved Technology. Because of the need for mainframe access, bulk file transfer, resource sharing, and interPC communications, the focus of user need will continue to shift towards data applications.[11] This expanding focus will require PBX manufacturers to develop higher switch throughput of about one Mbps.[12] Some vendors, such as Ztel, are already incorporating the necessary LAN-based technology into their PBX architectures. Spurred by the eventual analog-to-digital conversion of the public switched network, the need to access the ISDN, and the development of office automation environments, PBX offerings will become completely digital.[13]

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CHAPTER 7

CONCLUSION

The evolution of PBXs has lead to a point of no return; there will be no going back to the large, primitive, electromechanical switches of yesteryear. Each new improvement or innovation in telephone systems has brought with it new capabilities and features that rapidly make users wonder how they ever survived without them. Examples of these features, which have become almost mandatory in the office environment, are direct inward and outward dialing, call forwarding, and tone-dialing telephone sets. In addition, the advantages of digital technology are becoming more readily accepted, as more and more vendors design and sell digital switches.

However, ready acceptance of past innovations does not ensure a warm reception for present and future advances in communications technology. Integrated voice/data PBXs are a case in point. They represent a great step forward over earlier switches, which could, at best, handle small quantities of data at very low speeds. They offer many more features than a voice-only switch, including simultaneous voice and data transmission and mixed media communications. They

easily handle the commonest types of data transmissions found in a typical office, and give them access to resources and services that other data switches cannot touch. Yet, despite the obvious advantages, integrated PBXs have been met with caution and a "wait-and-see" attitude by many users.

This doubtful reception, however, has not been universal. Vendors have been quick to jump on the integration bandwagon, since it means sales of a new, profitable product for them. The telecommunications media, too, have embraced the integrated PBX as the hub of the automated office. They have touted its benefits loudly and consistently. Indeed, there has been more interest surrounding integrated PBXs than there has any other product, with the possible exception of LANs.

Some observers feel that much of the publicity is undeserved. They point to the high cost, which may include many marginal or unnecessary features, the speed limitations that preclude high speed applications, and the risk involved in putting two very different types of signals into one comunications system. The technology and the products are still too new and untested, and some of the companies too unstable, to have full confidence in the current state or the future of integrated PBXs.

Most of these complaints should be resolved in

the next decade. As the technology becomes more stable and economies of scale become available, the cost of integrated PBXs should decrease steadily. As processing power increases, more PBXs will incorporate LANs into their architecture in order to provide high speed transmission. This will be augmented by the continuing merger of PBX and computer manufacturers. A future market shakeout will lead eventually to more stable companies whose technology and promises can be trusted. With these improvements, the voice/data PBX will be a more attractive solution to office communications problems.

However, given the current state of the art, is an integrated PBX the best communications solution? Naturally, the answer will depend upon the type and size of the company, the nature of its data and voice communications requirements, and its telecommunications plans. Nevertheless, there are some situations in which an integrated PBX may be the best communications system to implement. These situations would occur:

* When a company needs to replace an old switch or Centrex service, or wants to upgrade a current switch (i.e., when it needs more functionality and features than either of the former can provide).

* When a company wants to upgrade its telephone sets from simple rotary dial or tone dial to more sophisticated sets with built-in memory and codecs, or possibly even IVDTs.

* When office data communications are mostly low speed, typical of common terminal types and PCs.

* When it is important that data remain in its original digital form, rather than being subject to the hazards of modulated analog transmission.

* When a firm wants to streamline transmissions by removing dual or multiple networks and disparate terminals.

* When a firm also desires to streamline management, operations and maintenance.

* When there is a high degree of growth and mobility within a firm, implying a need for terminals and telephone sets that are easily moved and reconfigured.

Given that these types of needs are fairly widespread today, the integrated PBX is meeting with increasing success. How it fares in the future will be

determined by the development efforts of the manufacturers and vendors. The voice/data PBX will never be a panacea for all office communications problems, but it will remain at the forefront of efforts to develop an automated office environment.

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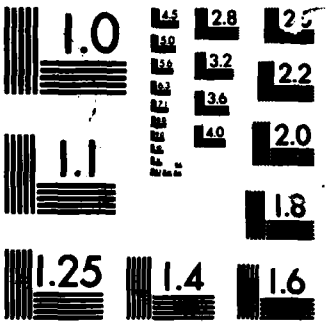

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APPENDIX A

VOICE DIGITIZATION

The world of telecommunications has been dominated for many years by analog transmission. While this technology is useful when dealing strictly with voice communications, it becomes inefficient when data is handled at the same time. Digital transmission is a better way to deal with voice and data simultaneously. If it were possible for the telecommunications industry to completely overhaul current telecommunications facilities, digital transmission facilities would be the status quo. However, the scale of economics in converting the public switched network from analog to digital prevents such a radical changeover. The change must come in small increments. On some links, it is still more profitable to use analog transmission. As the cost of using digital technology continues to drop, these links will be converted to digital.[1]

DIGITIZING THE VOICE SIGNAL

Human speech can be broadly catagorized into two types of sounds: voiced and voiceless. A voiced sound is produced by forcing air over the vocal chords in periodic pulses, causing the vocal chords to

vibrate. An example of a voiced sound is the letter "a". The period between air pulses, the pitch period, determines the frequency of the sound. Voiceless sounds, or fricatives, are formed when air is forced in a continuous stream over open (nonvibrating) vocal chords. The turbulance of the air flow rather than periodic air pulses is the excitation mechanism in this case. An example of a voiceless sound is the hiss in the word snake.[2] Any digital reproduction of speech must handle both methods of vocal excitation. Generally, there are two broad classes of voice digitization techniques: those that try to faithfully reproduce the analog waveform in digital form and those that try to encode only the perceptually-significant parts of the speech process.[3] This chapter will deal only with the first catagory as the second catagory does not relate specifically to voice/data integration in PBXs.

PULSE AMPLITUDE MODULATION

The first step in converting an analog waveform into a digital pulse train is to sample the waveform at periodic, uniform intervals. This produces a series of pulses representative of the original waveform where the height of the pulse is proportional to the amplitude of the analog signal at the sampling instant. Pulse height varies over an infinite set. This process

is called pulse amplitude modulation (PAM).[4]

The rate at which the waveform is sampled is critical in PAM. The minimum sampling frequency required to extract all information in an analog waveform was established in 1933 by Harry Nyquist. His sampling rule, the Nyquist criterion, states that the sampling frequency must be more than twice the bandwidth of the input signal. Stated mathematically, the criterion requires $f>2B$ where f is the sampling frequency and B is the bandwidth of the input signal. If sampling is done at less than the minimun required rate ($f<2B$), the original waveform cannot be fully recovered without experiencing foldover distortion or aliasing.[5] Since the most significant parameters of the human voice lie between about 300-3600 hertz (Hz), PAM sampling of a voice waveform is done at 8000 samples per second.[6]

In itself, PAM is insufficient to produce a digitized voice signal. It is still an analog representation even though it is a series of pulses. In addition, the vulnerability of individual PAM pulses to noise, distortion, and crosstalk makes it unsuitable for many applications.[7] To fully digitize the voice signal, a method must be used to produce a limited set of discrete pulse values that can be used to form digital code words. Though there are numerous techniques that can be used to accomplish this, only two

that are commonly found in integrated PBXs will be discussed. These two techniques are pulse code modulation (PCM) and delta modulation (DM).

PULSE CODE MODULATION

Pulse code modulation is an extension of PAM in that the PAM samples which vary infinitely in value are limited to a finite set of discrete values. This process is called quantization. When a PAM sample is quantized, it is subsequently represented as a digital code word. The number of bits in a code word is dependent on the number of quantization levels used. Generally, log(base 2) N bits would be needed per sample for N quantization levels.[8] The quantization process introduces error, called quantization noise, into the signal samples. Quantization noise can be kept to a minimum by having a large number of small quantization intervals. However, the number of bits required for coding increases as the number of quantization intervals increases. Using more bits per code word requires more bandwidth during transmission.[9]

Several variations of PCM are in use today: companded, 8-bit, mu-law PCM; companded, 8-bit, A-law PCM; and linear, 12-bit PCM.[10] Mu-law PCM and A-law PCM are both non-linear quantization techniques. Mu-law PCM is based on a compression parameter of 255

and is a standard in the United States. A-law PCM has a compression parameter of 87.6 and is used in Europe. Linear PCM is less common but is still used by some major PBX manufactureres such as Rolm.

DELTA MODULATION

Conventional PCM systems encode each speech sample completely independently of all other speech samples. Speech waveforms include considerable redundancy between adjacent samples. Generally, the correlation coefficient from one 8 kHz sample to the next is 0.85 or higher. Besides this type of correlation, there are other levels of redundancy in speech in both the time domain and the frequency domain. Conventional PCM coding does nothing to eliminate the redundancies of speech. Through the use of more efficient coding techniques, considerable savings in transmission bandwidth are possible.[11] Delta modulation (DM) is one such coding technique used to reduce the bit rate.

Delta modulation operates by transmitting a single bit per sample that indicates the direction of the waveform at the sampling instant. During DM, the waveform is approximated by increasing one quantization level when the difference from sample n-1 to sample n is positive and decreasing one level when the

difference is negative. In this way, the DM output moves back and forth across the input waveform. This allows for accurate reconstruction of the input signal by a smoothing filter.[12]

A system using DM must use a sampling rate much higher than the Nyquist minimum used by conventional PCM systems because each encoded sample contains only a relatively small amount of information. This "oversampling" allows better prediction from one sample to the next. Aside from the advantage of a lowered bit rate, DM also has an advantage in the simplicity of its implementation relative to conventional PCM. However. like any system that encodes the difference between samples in a signal, DM is susceptable to slope overload. Slope overload is a condition where the input signal is changing so rapidly that the delta modulator cannot keep up. Consequently, the modulator falls more than a step size behind. This creates distortion in the digitized voice signal.[13]

Like conventional PCM, DM is implemented in PBXs in different variations. Variations include linear DM (LDM) and a type of adaptive DM called continuously variable slope DM (CVSDM).[14] LDM uses a constant step size for all signal levels. CVSDM increases the step size with the onset of slope overload and reduces the step size as input slope decreases.

NOTES-APPENDIX A

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4. Martin, p. 267.

5. Bellamy, p. 86.

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8. Martin, p. 268.

9. Bellamy, p. 91.

10. S. Junker and W. Noller, "Digital Private Exchanges," IEEE Communications Magazine, vol. 21, no. 3, May 1983, p. 11.

11. Bellamy, p. 113.

12. Ibid, p. 125.

13. Ibid, p. 126.

14. Junker and Noller, p. 11.

APPENDIX B

ACRONYMS

AP	Application Processor
ASCII	American Standard Code for Information Interchange
AT&T	American Telephone and Telegraph
BOC	Bell Operating Company
CAD/CAM	Computer-Aided Design/Computer-Aide Manufacturing
CCITT	Consultative Committee for International Telephone and Telegraph
CO	Central Office
CPE	Customer Premise Equipment
CPI	Computer-to-PBX Interface
CPU	Central Processing Unit
CVSDM	Continual Variable Slope Delta Modulation
DCE	Data Communications Equipment
DCP	Digital Communications Procol
DEC	Digital Equipment Corporation
DLI	Data Line Interface
DM	Delta Modulation
DMI	Digital Multiplexed Interface
DOV	Data Over Voice
DTE	Data Terminal Equipment
DTI	Data Terminal Interface

EIA	Electronic Industries Association
FCC	Federal Communications Commission
FDX	Full Duplex
FSK	Frequency Shift Keying
Gbps	Gigabits Per Second
HP	Hewlett Packard
Hz	Hertz
IBM	International Business Machines
INL	Internode Link
INN	Internodal Network
I/O	Input/Output
ISDN	Integrated Services Digital Network
IVDT	Integrated Voice/Data Terminal
Kbps	Kilobits Per Second
KHz	Kilohertz
LAN	Local Area Network
LCR	Least Cost Routing
LDM	Linear Delta Modulation
Mbps	Megabits Per Second
MHz	Megahertz
NEC	Nippon Electronics Corporation
NTI	Northern Telecommunications Incorporated
PAM	Pulse Amplitude Modulation
PBX	Private Branch Exchange
PC	Personal Computer
PCM	Pulse Code Modulation

PSK	Phase Shift Keying
RBOC	Regional Bell Operating Company
RMU	Remote Multiplexor
SMDR	Station Message Detail Recording
SNA	System Network Architecture
SPC	Stored Program Control
SPU	System Processing Unit
TDM	Time-Division Multiplexing
WATS	Wide Area Telephone Service

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